Science 20
Course Outcomes
First Draft

May 1999

Revisions to this first draft will be made on the basis of advice and input received from questionnaires and advisory committees. A second (validation) draft is scheduled to be prepared for response in November 1999.

Unit Organization

In Grades 7–9, five units of study are outlined at each grade level. At grades 10–12, four units of study are outlined for each grade level. Each unit includes the following components.

Unit Overview

Each unit of study begins with an overview that introduces the contents of the unit and suggests an approach to its development.

Focussing Questions

These questions frame a context for introducing the unit and suggest a focus for investigative activities and application of ideas by students.

Key Concepts

Key concepts identify major ideas to be developed in each unit. Some of the key concepts may be addressed in additional units at the same grade/course level, as well as at other grade/course levels. The intended scope of treatment of these concepts is indicated by the learner outcomes.

Outcomes

Two levels of outcomes are provided in the draft program and courses of study:

- General Outcomes: These are the major outcomes for each unit. For STS and knowledge, the outcomes are combined and unique to each unit. For skills and attitudes, the outcomes are common to all units.
- Specific Outcomes: These are detailed outcomes that flesh out the scope of each unit. They are shown in bulleted form.

Examples

Many of the outcomes are supported by examples. The examples **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed. Illustrative examples are written in *italics* and separated from the outcomes by being placed in parentheses.

Unit Emphases

Each unit of study in secondary science begins with an overview and a set of focussing questions that identify a context for study. In defining the context, one of the following areas of emphasis is identified for each unit.

- *Nature of Science* emphasis: In these units student attention is focused on the processes by which scientific knowledge is developed and tested, and on the nature of the scientific knowledge itself. Skills emphasized in these units are the skills of scientific inquiry.
- *Science and Technology* emphasis: In these units students seek solutions to practical problems by developing and testing prototypes, products and techniques to meet a given need. The skills emphasized are those of problem solving, in combination with the skills of scientific inquiry.
- *Social and Environmental Contexts* emphasis: In these units student attention is focused on issues and decisions relating to how science and technology are applied. Skill emphasis is on the use of research and inquiry skills to inform decisions; students seek and analyze information and consider a variety of perspectives.

Unit A: The Changing Earth *(Nature of Science emphasis)*

Overview: Over the last 3.5 billion years, change has been the only constant in our planet's history. There is evidence not only that Earth's surface is changing but also that the climate and life forms on Earth have undergone dramatic changes. This unit builds upon Science 10, Unit D: Energy Flow in Global Systems to examine scientific evidence for natural causes of climate change, for changing life forms and for continual changes to Earth's surface.

Focussing Questions: What is the scientific evidence for change to Earth? How has this evidence been used to formulate scientific theories? What are the limitations of current theories in making predictions about future Earth changes?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ layers of Earth
- ☆ evidence for the theory of plate tectonics
- ☆ energy transmission in earthquakes
- ☆ radiometric dating and half-life
- ☆ fossilization
- ☆ evidence for evolution gradualism versus punctuated equilibrium
- ☆ formation of fossil fuels
- ☆ evidence for variations in Earth's climate

STS and Knowledge Outcomes

Students will:

1. Analyze the nature of scientific evidence and explanations for geological phenomena that occurred a long time ago or that are taking place over a longer period of time
   - compare and describe the challenges in investigating the movements of Earth's crustal plates, past climates and life forms that take place over hundreds of millions of years, to investigating earthquakes and seismic waves
   - describe, in general terms, how the theories of geological processes have changed over time due to the contributions of Hutton, Lyell and Wegener
   - explain the importance of technology to facilitate the study of changes to Earth's surface, climate and life forms—enhancing the gathering of data, its quality, accuracy and precision *(e.g., seismometers, radiometric dating technologies, sonar mapping of ocean floor, GPS to measure plate movement)*

2. Analyze and assess the evidence to explain the theory of plate tectonics and the internal structure of the Earth
   - describe how energy from earthquakes is transmitted by seismic waves
   - describe the relationship between the Richter scale and an earthquake's ground motion and energy
   - distinguish between P- and S- seismic waves, on the basis of vibrations and direction of propagation
   - explain how seismic waves are used to better understand the internal structure of Earth
   - identify and describe the layers of Earth as classified by physical properties; i.e., lithosphere, asthenosphere and mesosphere; outer and inner core in terms of density, rigidity and thickness
   - describe the need for more accurate predictions of earthquakes and the limitations of current knowledge in predicting earthquakes

- list and describe the evidence that supports the theory of plate tectonics *(e.g., location of volcanoes and earthquakes, ocean floor spreading, mountain ranges, age of sediments, paleomagnetism)*
- explain how convection circulation of molten material provides the driving force of plate tectonics, and explain the tentativeness of the explanation that radioactive decay is the source of geothermal energy for plate tectonics
- assess the theory of plate tectonics in terms of its ability to explain and predict changes to Earth's surface *(e.g., lack of knowledge of how plates move, their driving force and the nature of past plate tectonics make predictions difficult)*

3. Analyze and assess the evidence provided by the fossil record to indicate that the environment and life forms have changed over a period of 3.5 billion years
   - explain how knowledge of radioisotopes, radioactive decay and half-life are used to estimate the age of minerals and fossils
   - describe common types of fossilization; i.e., actual remains, molds or imprints, track, trail or burrow, as direct evidence of evolution, and describe the significance of Canada's Burgess Shale
   - explain how sedimentary rock layers along with fossils can provide evidence of chronology, paleoclimate, evolution and mass extinctions *(e.g., fossils of reptiles and certain types of plants usually indicates a warm tropical climate; zone, index and transitional fossils)*
   - describe, in general terms, the major characteristics and life forms of the four eras: Precambrian, Paleozoic, Mesozoic and Cenozoic
   - explain why oxygen was not a significant component of Earth's atmosphere until the evolution of plants and chlorophyll
   - compare gradual evolution with the newer punctuated equilibrium view, in terms of the evidence and explanatory power

4. Analyze the evidence and assess the explanations for natural variations in Earth's climate over the last two million years
   - describe the geologic evidence for repeated glaciation over large areas of Canada and in their local area *(e.g., gold deposits in the Yukon, Cyprus Hills, topography, drainage patterns, erratics, U-shaped valleys)*
   - explain how ice cores from polar icecaps provide evidence of warming and cooling in the past hundred thousand years
   - explain, in general terms, how changes to Earth's climate and some mass extinctions could be caused by orbit around the Sun, changes to the inclination of Earth's axis, variations in solar energy output, changes in Earth's geography due to crustal movement, volcanic activity and changes to the composition of the atmosphere
   - describe the limitations of current models to predict changes to climate in a geological time frame

Skill Outcomes *(focus on scientific inquiry)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- define and delimit problems to facilitate investigation *(e.g., locate the approximate epicentre of an earthquake, using data provided)*
- design an experiment, identifying manipulated, responding and controlled variables

information; identify and analyze a variety of factors that affect the authenticity of information derived from the mass media and electronic communication)

- identify and explain sources of error and uncertainty in measurement, and express results in a form that acknowledges the degree of uncertainty *(e.g., describe earlier life forms on the basis of fossil evidence)*
- provide a statement that addresses the problem or answers the question investigated, in light of the link between the data and the conclusion *(e.g., distinguish between cause, effect or correlation when describing causes of mass extinction or natural variations in climate change)*
- explain how data support or refute the hypothesis or prediction
- identify new questions or problems that arise from what was learned *(e.g., "Is the rate of species extinction today the same as those during periods of mass extinction?")*
- identify and evaluate potential applications of findings *(e.g., investigate the application of S-waves and P-waves in designing earthquake-proof buildings)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- communicate questions, ideas and intentions; and receive, interpret, understand, support and respond to the ideas of others *(e.g., use appropriate communication technology to elicit feedback from others; participate in a variety of electronic group formats)*
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., use advanced menu features within a word processor to accomplish a task to insert tables, graphs, text and graphics; select and use multimedia capabilities for presentation)*
- synthesize information from multiple sources, or from complex and lengthy texts, and make inferences based on this information *(e.g., record relevant data for acknowledging sources of information, and cite sources correctly; use integrated software effectively and efficiently to reproduce work that incorporates data, graphics and text)*

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not *(e.g., consider the social and cultural contexts in which a theory developed; recognize the usefulness of being skilled in mathematics and problem solving; appreciate how scientific problem solving and the development of new technologies are related)*

Interest in Science

Students will be encouraged to:

- show a continuing and more informed curiosity and interest in science and science-related issues *(e.g., research the answers to their own questions; recognize the importance of making connections between various science disciplines; explore and use a variety of methods and resources to increase their own knowledge and skills; be critical and constructive when considering new theories and techniques)*

- state a prediction and a hypothesis based on available evidence and background information *(e.g., use local average temperatures to predict average temperatures 100 years from now)*
- identify the theoretical basis of an investigation, and develop a prediction and a hypothesis that are consistent with the theoretical basis *(e.g., investigate Canada's earthquake prone areas, and predict likely locations of a future earthquake)*
- evaluate and select appropriate instruments for problem solving, inquiring and decision making *(e.g., decide what needs to be measured, and select the proper procedures and tools for the task; select and use appropriate technology for a task)*
- develop appropriate sampling procedures *(e.g., to collect ice core samples from ice fields around the world for a study of climate over the past 2 million years)*

Performing and Recording

Students will:

Conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information

- use instruments effectively and accurately for collecting data *(e.g., use stereoscopes to view aerial photographs of glaciers)*
- estimate quantities *(e.g., estimate, predict, check and validate calculations when determining the location of earthquakes)*
- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data *(e.g., investigate monthly occurrences of earthquakes, their intensity and locations around the world)*
- select and use apparatus technology and materials safely *(e.g., apply safety regulations specific to the technology being used; identify and apply safety procedures, including antivirus scans and virus checks to maintain data integrity)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible explanations

- describe and apply classification systems and nomenclatures used in the sciences *(e.g., apply units of geologic time, eras, periods and epochs)*
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., manipulate and present data through the selection of appropriate tools, such as scientific instrumentation, calculators, databases or spreadsheets)*
- identify a line of best fit on a scatterplot, and interpolate or extrapolate based on the line of best fit *(e.g., interpret simple stratigraphic sequences)*
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables *(e.g., interpret decay curves of common radioactive dating elements)*
- apply and assess alternative theoretical models for interpreting knowledge in a given field *(e.g., compare the theories of continental drift and plate tectonics)*
- evaluate the relevance, reliability and adequacy of data and data collection methods *(e.g., assess the authority, reliability and validity of electronically-accessed information; evaluate the appropriateness of the technology used to investigate or solve a problem)*
- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information *(e.g., assess the authority, reliability and validity of electronically-accessed*

Unit B: Changes in Living Systems *(Social and Environmental Contexts emphasis)*

Overview: Matter cycles and energy flows through the biosphere, the component ecosystems, and between living systems and the physical environment. This unit extends and builds on the concepts introduced in Science 9, Unit A: Biological Diversity; Science 10, Unit D: Energy Flow in Global Systems; and Science 20, Unit A: The Changing Earth. Ecosystems change over time. In turn, populations of plants and animal species also adapt to their changing environment. Students understand that the ability of organisms to adapt to their environment depends on variation, fitness, natural selection and population growth. However, students also learn that due to human interventions, ecosystems are changing more rapidly than the ability of organisms to adapt.

Focussing Questions: How does matter cycle and energy flow through the biosphere, and what are the implications of this knowledge for protecting the environment for future generations? What are the characteristics of an ecosystem, and what happens to ecosystems and organisms as a result of natural and artificial interventions?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ biogeochemical cycles of carbon, nitrogen and oxygen
- ☆ energy flow through trophic levels, biomass, autotrophs, heterotrophs
- ☆ food chains, webs
- ☆ effects of biotic and abiotic factors on ecosystems
- ☆ succession, natural and artificial disturbances, introduction of species to ecosystems, adaptation of organisms
- ☆ determining adaptation, evidence for evolution
- ☆ population size and limiting factors

STS and Knowledge Outcomes

Students will:

1. Analyze and investigate the flow of matter and energy through the biosphere, and how society and the environment are interdependent with scientific and technological endeavours
   - outline the biogeochemical cycles of carbon, water (Science 10) and nitrogen, and in general terms, outline their interconnectedness
   - describe the effects of increased levels of atmospheric CO_2 and deforestation on the carbon cycle, the effects of agricultural run-off and the effects of waste water on the water cycle
   - assess if deep-well injection of wastes is a viable alternative, by taking into consideration a number of perspectives and ideas *(e.g., properties of waste, concentration, uncertainty, environmental concerns, risks and benefits to human health and organisms, costs)*
   - analyze and describe how energy moves through trophic levels, using the concepts of food webs and food chains and using specific examples of autotrophs and heterotrophs
   - analyze the energy budget of an ecosystem, in terms of energy input and output through the trophic levels, and of a consumer to explain why populations of species at higher trophic levels decrease
   - assess the impact of shortening the food chain for humans, in terms of energy efficiency and in meeting food requirements for an increasing population
   - contrast the diet of people in developing countries with the diet of people in developed countries

- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research *(e.g., use scientific vocabulary and principles in everyday discussions)*
- consider further studies and careers in science- and technology-related fields *(e.g., maintain interest or pursue further studies in science; explore where further science- and technology-related studies can be pursued)*

Scientific Attitudes

Students will be encouraged to:

- evaluate evidence confidently, and consider alternative perspectives, ideas and explanations *(e.g., insist on evidence before accepting a new idea or explanation; critically evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation; critically assess their opinion of the value of science and its application)*
- use factual information and rational explanations when analyzing and evaluating *(e.g., insist that the critical assumptions behind any line of reasoning be made explicit, so that the validity of the position taken can be judged)*
- value the processes for drawing conclusions *(e.g., ask questions and do research to ensure they understand; recognize the importance of reviewing the basic assumptions from which a line of inquiry has arisen; expend the effort and time needed to make valid inferences; seek new models, explanations and theories when confronted with discrepant events)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., work willingly with any classmate or group of individuals, regardless of age, gender, or physical and cultural characteristics; provide the same attention and energy to the group's product as they would to a personal assignment)*

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., consider safety a positive limiting factor in scientific and technological endeavours; assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials in a safe place)*

- identify questions to investigate that arise from practical problems and issues *(e.g., does logging provide deer with more food resources, or does it make it easier for predators to find the deer)*
- design an experiment, and identify specific variables *(e.g., investigate relationships between abiotic and biotic environments in a micro ecosystem)*
- state a prediction and a hypothesis based on available evidence and background information *(e.g., predict the impact of fishing or forestry on an aquatic or terrestrial ecosystem respectively)*
- formulate operational definitions of major variables *(e.g., define biotic and abiotic factors, food webs, biomagnification)*
- evaluate and select appropriate instruments for problem solving, inquiring and decision making *(e.g., decide what needs to be measured, and select the proper procedures and tools for the task; select and use appropriate technology for a task: "Are economic activity and environmental protection mutually exclusive?")*
- develop appropriate sampling procedures *(e.g., to conduct a field study of a terrestrial or aquatic ecosystem)*

Performing and Recording

Students will:

Conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information

- implement appropriate sampling procedures *(e.g., to conduct a field study of a terrestrial or aquatic ecosystem)*
- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data *(e.g., conduct a field study of an ecosystem, and identify components of the ecosystem—describe biotic factors, measure and identify abiotic factors, describe community interactions, identify topographical factors and measure populations)*
- use library and electronic research tools to collect information on a given topic *(e.g., debate the issue: protecting the environment should have priority over economic interests; use current, reliable information sources from around the world on endangered species; demonstrate proficiency in uploading and downloading text, image, audio and video files)*
- select and integrate information from various print and electronic sources *(e.g., create multiple-link documents appropriate to the content of the particular topic; search government publications, and gather relevant information on sustainable development initiatives)*
- select and use apparatus and materials safely *(e.g., use a pH meter and sampling nets for collecting data in the study of an aquatic ecosystem)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible explanations

- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., manipulate and present data through the selection of appropriate tools, such as scientific instrumentation, calculators, databases or spreadsheets; present statistical data in diagrams, tables and graphs as part of a brief for a public hearing on a proposed mineral exploration in an ecologically sensitive area; analyze population data charts, tables and graphs)*
- evaluate the relevance, reliability and adequacy of data and data collection methods *(e.g., assess the authority, reliability and validity of electronically-accessed information; evaluate the*

2. Analyze ecosystems and succession in the local area, in terms of species diversity and how society and the environment are interdependent with scientific and technological endeavours
   - distinguish between biotic and abiotic factors
     - explain, in general terms, the relationship between climatic factors explored in Science 10, Unit D: Energy Flow in Global Systems and ecosystems
     - describe, in general terms, the physiographic and edaphic factors that influence ecosystems
     - describe, in general terms, symbiosis, predation and competition (interspecific and intraspecific)
   - analyze and investigate an aquatic or terrestrial local ecosystem, and infer relationships among organisms *(e.g., predator–prey relationships, species-specific interactions, types of symbiosis)*
   - describe primary and secondary succession as natural processes of change over time in an ecosystem
     - describe key stages of primary succession in a specific aquatic and terrestrial ecosystem (e.g., bog, pond, sand dune, river, lake)
     - describe possible pathways of secondary succession in an ecosystem
   - compare natural and artificial means to change secondary succession in an ecosystem *(e.g., reforestation or regrowth after a forest fire, strip mining, clear cutting, natural disaster)*
   - describe the effects of introducing a new species into an environment *(e.g., rabbits and the cane toad in Australia, the Eurasian milfoil in Canada's lakes)*
   - analyze the need for habitat reclamation, and describe steps to reduce the impact on sustainability and species diversity *(e.g., recreating wetlands and swamps, forests, prairie grasslands)*

3. Analyze and describe the adaptation of organisms to their environments, limiting factors of natural populations, and Darwin's ideas on science and society
   - list and explain the factors that limit the size of populations, and discuss if the growth pattern of human populations differs from the populations of other organisms
   - describe the inherited and non-inherited variations in species and populations
   - describe the role and influence of variation, fitness, natural selection and population growth on the adaptation of organisms to their environments
   - analyze the homologous structures in a range of fossil and living species, and infer the adaptive significance as indirect evidence of evolution—fossils in Science 20, Unit A are a direct evidence of evolution
   - describe the major observations synthesized by Darwin to propose the theory of evolution by natural selection *(e.g., overproduction, competition, variation, adaptation, natural selection, survival of the fittest and speciation)*
   - assess the impact of the increased human population on human diet, diversity and population of other species; and assess if the human population has exceeded Earth's carrying capacity despite technological innovations increasing food supply
   - describe how Darwin's ideas have profoundly affected social thought and science *(e.g., "social Darwinism" and the concept of "racial superiority"; "evolution" of social organizations)*

Skill Outcomes *(focus on applying science to inform decision-making processes)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

appropriateness of the technology [deep-well injection of wastes] used to investigate or solve a problem)

- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information *(e.g., assess the authority, reliability and validity of electronically-accessed information; identify and analyze a variety of factors that affect the authenticity of information derived from the mass media and electronic communication)*
- identify new questions or problems that arise from what was learned *(e.g., "Should naturally occurring forest fires be fought?")*
- identify and evaluate potential applications of findings *(e.g., apply the growth curve for open populations to identify the long-term impact on Earth's carrying capacity and the demands on natural resources for a growing human population)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- communicate questions, ideas and intentions; and receive, interpret, understand, support and respond to the ideas of others *(e.g., use appropriate communication technology to elicit feedback from others; participate in a variety of electronic group formats; prepare a visual display explaining initiatives taken by industry to protect the environment)*
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., use advanced menu features within a word processor to accomplish a task to insert tables, graphs, text and graphics for food webs and energy budgets for various trophic levels in an ecosystem)*
- identify multiple perspectives that influence a science-related decision or issue *(e.g., consult a wide variety of sources that reflect varied viewpoints on particular topics, such as Darwin's impact on modern science and society)*
- develop, present and defend a position or course of action. based on findings *(e.g., make arguments for a vegetarian diet)*
- work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise *(e.g., develop a plan, seek feedback, test and review it, make revisions, and implement it)*
- evaluate individual and group processes used in planning, problem solving, decision making and completing a task

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- appreciate that the applications of science and technology can raise ethical dilemmas *(e.g., use a multi-perspective approach, considering scientific, technological, economic, cultural, political and environmental factors when formulating conclusions, solving problems or making decisions on an STS issue; carefully research and openly discuss ethical dilemmas associated with the applications of science and technology)*
- value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds *(e.g., recognize the contribution of science and technology to the progress of civilizations; recognize that western approaches to science are not the only ways of viewing the universe; consider the research of both men and women)*

Interest in Science

Students will be encouraged to:

- show a continuing and more informed curiosity and interest in science and science-related issues *(e.g., explore and use a variety of methods and resources to increase their own knowledge and skills; be interested in science and technology topics not directly related to their formal studies)*
- consider further studies and careers in science- and technology-related fields *(e.g., maintain interest or pursue further studies in science)*

Scientific Attitudes

Students will be encouraged to:

- evaluate evidence confidently, and consider alternative perspectives, ideas and explanations *(e.g., insist on evidence before accepting a new idea or explanation; critically assess their opinion of the value of science and its applications; criticize arguments in which evidence, explanations or positions do not reflect the diversity of perspectives that exist)*
- use factual information and rational explanations when analyzing and evaluating *(criticize arguments based on the faulty, incomplete or misleading use of numbers; insist that the critical assumptions behind any line of reasoning be made explicit, so that the validity of the position taken can be judged)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., be attentive when others speak; seek the point of view of others, and consider a multitude of perspectives)*

Stewardship and Ethical Behaviour

Students will be encouraged to:

- have a sense of personal and shared responsibility for maintaining a sustainable environment *(e.g., assume part of the collective responsibility for the impact of humans on the environment; participate in civic activities related to the preservation and judicious use of the environment and its resources; encourage their peers or members of their community to participate in a project related to sustainability)*
- project the personal, social and environmental consequences of proposed action *(e.g., consider all perspectives when addressing issues, weighing scientific, technological and ecological factors; discuss both the positive and negative effects on human beings and society of environmental changes caused by nature and by humans)*
- want to take action for maintaining a sustainable environment *(e.g., participate in civic activities related to the preservation and judicious use of the environment and its resources; participate in the social and political systems that influence environmental policy in their community; willingly promote actions that are not injurious to the environment; make personal decisions based on a feeling of responsibility toward less privileged parts of the global community and toward future generations; be critical-minded regarding the short- and long-term consequences of sustainability)*

Unit C: Chemical Changes *(Science and Technology emphasis)*

Overview: Chemical changes involve a change in energy. The production of many useful materials requires an understanding of oxidation–reduction and the characteristics of hydrocarbons. Students learn that economically important industries in Alberta and other parts of Canada are based upon the application of chemical principles. These chemical principles are extended from those first introduced in Science 10, Unit A: Energy and Matter in Chemical Change.

Focussing Questions: How are characteristics of aqueous solutions applied in solving practical problems? How has knowledge about oxidation–reduction and characteristics of hydrocarbons been applied to solve practical problems?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ properties of electrolytes, nonelectrolytes
- ☆ measuring concentrations in moles per litre and parts per million
- ☆ spontaneous and non-spontaneous redox reactions
- ☆ application of oxidation–reduction in solving practical problems
- ☆ operation of galvanic and electrolytic cells
- ☆ general characteristics of hydrocarbons
- ☆ naming alkanes, alkenes, alkynes (3 carbon limit)
- ☆ classifying important hydrocarbon reactions
- ☆ Alberta's ethylene and polyethylene industry

STS and Knowledge Outcomes

Students will:

1. Analyze large-scale industrial processes to recognize chemical reactions
   - provide examples of materials used in daily life that are based upon Alberta's petrochemical industry and involve changes in energy *(e.g., manufacture of plastics, gasoline)*
   - list examples of important applications to produce energy from chemical change, extraction of metals and protection from corrosion
   - describe the need for industrial processes to make use of efficient designs to provide optimal yields within constraints of costs and requirements for sustainability

2. Investigate and describe the properties of aqueous solutions that provide a convenient medium for oxidation–reduction reactions, and investigate and describe applications of these reactions in solving practical problems
   - provide examples of how dissolving substances in water is often a prerequisite for chemical change *(e.g., galvanic cells)*
   - differentiate, on the basis of properties, among electrolytes and nonelectrolytes
   - compare the ways, and explain the reasons for how, concentrations are expressed in the laboratory, in household products and in environmental studies, in terms of moles/litre, per cent and parts per million (ppm)
   - determine the concentration of solutions, in terms of moles per litre, per cent by volume and parts per million—stoichiometric methods are not required
   - determine the concentration of diluted solutions and the quantities of solute and solvent to use when diluting

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., criticize a procedure, a design or materials that are not safe or that could have a negative impact on the environment; consider safety a positive limiting factor in scientific and technological endeavours)*
- be aware of the direct and indirect consequences of their actions *(e.g., carefully manipulate materials, being cognizant of the risks and consequences of their actions)*

- design an experiment, and identify specific variables *(e.g., determine relative reactivity of metals with electrolytic solutions)*
- state a prediction and a hypothesis based on available evidence and background information *(e.g., predict spontaneous reactions, using an activity series; predict the products of simple reactions)*
- formulate operational definitions of major variables *(e.g., anode, cathode)*
- evaluate and select appropriate instruments for problem solving, inquiring and decision making *(e.g., decide what needs to be measured, and select the proper procedures and tools for the task; investigate a galvanic cell or make a battery; select and use appropriate technology for a task; perform an Internet search to prepare biographies of Volta and Galvani; conduct "virtual" labs on spontaneous and non-spontaneous redox reactions)*

Performing and Recording

Students will:

Conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information

- use instruments effectively and accurately for collecting data *(e.g., use a voltmeter, ammeter)*
- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data *(e.g., determine which cell or battery is best for a CD player, or a specific device)*
- demonstrate a knowledge of WHMIS standards, by selecting and applying proper techniques for handling and disposing of laboratory materials *(e.g., handle electrolytic solutions safely and appropriately)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible explanations

- describe and apply classification systems and nomenclatures used in the sciences *(e.g., classify alkanes, alkenes and alkynes)*
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., collect data on melting and boiling points of hydrocarbons and the reactivity of metals with electrolytic solutions; draw a flow chart, illustrating catalytic cracking or the function of galvanic and electrolytic cells)*
- evaluate the relevance, reliability and adequacy of data and data collection methods *(e.g., assess the authority, reliability and validity of electronically-accessed information; evaluate the appropriateness of the technology used to investigate or solve a problem)*
- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information *(e.g., assess the authority, reliability and validity of electronically-accessed information; identify and analyze a variety of factors that affect the authenticity of information derived from the mass media and electronic communication)*
- provide a statement that addresses the problem or answers the question investigated, in light of the link between data and the conclusion *(e.g., delineate cause, effect or correlation between ozone depletion and levels of CFCs)*
- identify and correct practical problems in the way a technological device or system functions
- construct and test a prototype of a device or system, and troubleshoot problems as they arise *(e.g., construct an electrolytic cell)*

- describe single replacement reactions (Science 10) as redox reactions
- determine the reactivity of metals with various electrolytic solutions
- define, operationally, oxidation and reduction and spontaneous and non-spontaneous reactions *(e.g., loss of electrons is oxidation, gain of electrons is reduction, a spontaneous redox reaction produces electrical energy from chemical change, and a non-spontaneous redox reaction requires electrical energy to produce chemical change)*
- apply the principles of oxidation–reduction and half-reactions, where applicable, to describe in general terms the operation of galvanic and electrolytic cells *(e.g., a galvanic cell uses chemical change to produce electrical energy, and an electrolytic cell uses electrical energy to produce chemical change; batteries, metal extraction, cathodic protection, galvanizing, electroplating)*

3. Investigate and describe the properties of simple hydrocarbons and hydrocarbon-based industrial processes that are important to Alberta
   - identify the physical characteristics of hydrocarbons, including melting and boiling points and solubility of alkanes, alkenes and alkynes
   - provide International Union of Pure and Applied Chemistry (IUPAC) names and structural formulas for simple and non-cyclic hydrocarbons in the homologous series of alkanes, alkenes and alkynes involving up to three carbon atoms
   - identify hydrocarbons as a source of fossil fuels, and explain the processes of fractional distillation to refine petroleum and catalytic cracking to produce ethene (ethylene)
   - balance, classify and apply mole ratios to important hydrocarbon reactions:
     - substitution/replacement reaction of alkanes with chlorine to produce CFCs
     - combustion of hydrocarbons to produce carbon dioxide, water vapour and energy
     - production of ethene (ethylene) from catalytic cracking
     - hydrogenation of alkenes (unsaturated) to produce alkanes (saturated)
     - production of alcohol and plastics from ethene (ethylene)/polyethene (polyethylene)

4. Describe the relationship between the knowledge about chemical reactions and technological applications of this knowledge in industrial processes
   - analyze technological products and processes in terms of scientific principles:
     - commercial production of ethylene and polyethylene
     - batteries, metal extraction, cathodic protection, galvanizing, fuel cell
   - list challenges when taking scientific knowledge from the laboratory and applying the knowledge to large-scale manufacturing processes or developing products *(e.g., supply of raw materials, energy, labour, storage and disposal of waste products)*
   - explain, using relevant examples, that technological products and processes meet needs but also have environmental implications, risks and benefits, and spin-offs *(e.g., production of smaller and longer lasting batteries and their disposal)*

Skill Outcomes *(focus on problem solving)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- identify questions to investigate that arise from practical problems and issues *(e.g., investigate ways to reduce the corrosion of pipelines or automobiles)*

Interest in Science

Students will be encouraged to:

- consider further studies and careers in science- and technology-related fields *(e.g., recognize that part-time jobs require science- and technology-related knowledge and skills; explore where further science- and technology-related studies can be pursued)*

Scientific Attitudes

Students will be encouraged to:

- evaluate evidence confidently, and consider alternative perspectives, ideas and explanations *(e.g., critically evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation; critically assess their opinion of the value of science and its applications; criticize arguments in which evidence, explanations or positions do not reflect the diversity of perspectives that exist)*
- use factual information and rational explanations when analyzing and evaluating *(e.g., criticize arguments based on the faulty, incomplete or misleading use of numbers; insist that the critical assumptions behind any line of reasoning be made explicit, so that the validity of the position taken can be judged)*

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., explore personal perspectives, attitudes and beliefs toward Alberta's petrochemical industries)*

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., read the labels on materials before using them, interpret the WHMIS symbols, and consult a reference document if safety symbols are not understood; consider safety a positive limiting factor in scientific and technological endeavours; assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials in a safe place; seek assistance immediately for any first aid concerns, such as cuts, burns or unusual reactions; keep the work station uncluttered, with only appropriate laboratory materials present)*
- be aware of the direct and indirect consequences of their actions *(e.g., carefully manipulate materials, being cognizant of the risks and consequences of their actions; write into a laboratory procedure safety and waste-disposal concerns; use safety and waste disposal as criteria for evaluating an experiment)*

- propose alternative solutions to a given practical problem. identify the potential strengths and weaknesses of each, and select one as the basis for a plan
- evaluate a personally designed and constructed device on the basis of criteria they have developed themselves *(e.g., evaluate a process or device that prevents rusting in iron)*
- identify new questions or problems that arise from what was learned *(e.g., "How are commercially available batteries recharged?")*
- identify and evaluate potential applications of findings *(e.g., "What is the environmental impact of electric cars?")*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

- communicate questions, ideas and intentions; and receive, interpret, understand, support and respond to the ideas of others *(e.g., use appropriate communication technology to elicit feedback from others; participate in a variety of electronic group formats when developing criteria to assess the sustainability of gasoline, or propane, or battery-powered vehicles)*
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., select and use multimedia capabilities for presenting perspectives on the desirability of an oil refinery being located in their local community)*
- synthesize information from multiple sources or from complex and lengthy texts, and make inferences based on this information *(e.g., record relevant data for acknowledging sources of information, and cite sources correctly; use integrated software effectively and efficiently to reproduce work that incorporates data, graphics and text; rate, in terms of sustainability, the following technologies: gasoline, or propane, or battery-powered vehicles)*
- identify multiple perspectives that influence a science-related decision or issue *(e.g., consult a wide variety of sources that reflect varied viewpoints on particular topics, such as "Should plastics be burned for fuel or put in landfills?")*
- develop, present and defend a position or course of action, based on findings *(e.g., debate the desirability of an oil refinery being located in their local community)*
- evaluate individual and group processes used in planning, problem solving and decision making, and completing a task *(e.g., review, as a group, the individual contributions to a team-assigned task)*

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not *(e.g., appreciate how scientific problem solving and the development of new technologies are related; recognize the contribution of science and technology to the progress of civilizations)*
- value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds *(e.g., recognize the contribution of science and technology to the progress of civilizations; consider the research of both men and women)*

3. Describe and analyze the law of conservation of momentum for one-dimensional collisions and change in momentum (impulse) to describe how force affects motion
   - define momentum as "quantity of motion" equal to the product of the mass and velocity of an object, $\bar{p} = m\bar{v}$
   - apply the law of conservation of momentum to one-dimensional collisions and explosions, using scale diagrams and numerical calculations *(e.g., apply $m_1\bar{v}_1 + m_2\bar{v}_2 = m_1\bar{v}_1' + m_2\bar{v}_2'$ to traffic accidents involving two vehicles)*
   - define change in momentum as impulse ($\Delta\bar{p} = m\Delta\bar{v} = \bar{F}_{ave}\Delta t$), relate impulse to acceleration and Newton's second law of motion ($\Delta\bar{p}/\Delta t = m\bar{a} = \bar{F}$), and apply the concept of impulse to explain the functioning of a variety of safety devices *(e.g., airbags, collapsible frames, bumpers, seat belts in cars, restraining nets and crash barriers on highways, collapsible steering wheels, padded dashboards, and padding in helmets, goggles and gloves are all designed to increase the stopping time or time of contact, by reducing acceleration and, thereby, force)*
   - explain how an unbalanced force causes change in motion, and apply Newton's first law of motion to explain an object's state of rest or uniform motion *(e.g., movement of passengers in a moving car that accelerates or is coming to a stop)*
   - apply Newton's second law of motion and use it to relate force, mass and motion *(e.g., explanation of a whiplash injury when involved in a rear-end collision)*
   - apply Newton's third law of motion to explain the interaction between two objects

4. Assess safety technologies in terms of functional design, costs, risks and benefits, and unintended consequences
   - trace the development of safety technologies in sports or transportation over the past 50 years, and compare the functioning of first and current generation safety technologies *(e.g., sports safety equipment [helmets, face masks, gloves]; automobile safety devices [lap belts, shoulder belts, air bags])*
   - analyze automobile and sports equipment safety features with a view to reduce risks within contextual constraints *(e.g., costs, materials, weight and requirements for sustainability; rules)*
   - analyze the design of stop and go zones, and propose improvements to the design of traffic lights and intersections

Skill Outcomes *(focus on problem solving)*

Initiating and Planning

Students will:

Ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues

- identify questions to investigate that arise from practical problems and issues *(e.g., "How can sports equipment be made more safe?", "Do you increase protection or change the rules to make hockey safer?")*
- evaluate and select appropriate instruments for problem solving, inquiring and decision making *(e.g., decide what needs to be measured, and select the proper procedures and tools for the task; select and use appropriate technology for a task; use spreadsheets for analyzing velocity, acceleration, displacement and the law of conservation of momentum, assessing the design of traffic lights and intersections)*

Unit D: Changes in Motion *(Science and Technology emphasis)*

Overview: Motion is an important aspect of our lives, and the understanding of the effects of force on motion has many technological applications. Students learn that these applications can range from the design of safer roads and sports equipment to the investigation of traffic accidents. This unit extends the concepts of speed and distance from Science 10, Unit B: Energy Flow in Technological Systems to include velocity, displacement and acceleration.

Focussing Questions: How does the design of safety equipment and systems take into account concepts of changes in motion and forces? What has been the influence of society on the development of safety technology, and what are the contextual constraints and limits of these technological solutions?

Key Concepts

The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes below.

- ☆ description of motion in terms of displacement, time, velocity, acceleration (kinematics)
- ☆ conservation of momentum in one-dimension
- ☆ impulse and force
- ☆ Newton's three laws of motion
- ☆ application of Newton's laws of motion and momentum in the design of sports and transportation safety devices

STS and Knowledge Outcomes

Students will:

1. Describe technologies used to solve practical problems of ensuring human safety involving changes in motion
   - list the risks from greatest to least in a variety of day-to-day transportation and sporting situations and the technologies designed to reduce the risk of injury
   - describe the influence of societal perceptions of risk and scientific knowledge on the development of safety technologies designed to control changes in motion
   - describe the need for safety technologies and regulations for transportation and sporting situations

2. Describe the one-dimensional motion of objects in terms of displacement, time, velocity and acceleration
   - distinguish between scalar and vector quantities: speed and velocity, distance and displacement
   - define velocity and acceleration as $\vec{v} = \Delta\vec{d}/\Delta t$ and $\vec{a} = \Delta\vec{v}/\Delta t$ respectively
   - determine velocity, displacement and acceleration from position–time and velocity–time graphs
   - determine displacement in uniform motion and uniform accelerated motion, using the relationships $\vec{d} = \vec{v}_i t + \frac{1}{2}at^2$ and $\vec{d} = \frac{(\vec{v}_i + \vec{v}_f)}{2}t$
   - apply principles of one-dimensional uniform motion to analyze and graph relevant traffic safety design features *(e.g., safe lengths of freeway entrance and exit ramps, traffic lights with advance warning flashers, length of time lights stay yellow and types of intersections, comparing stopping distances and accelerations of cars)*

- communicate questions, ideas and intentions; and receive, interpret, understand, support and respond to the ideas of others *(e.g., use appropriate communication technology to elicit feedback from others; participate in a variety of electronic group formats)*
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results *(e.g., use advanced menu features within a word processor to accomplish a task to insert tables, graphs, text and graphics; select and use multimedia capabilities for presentation)*
- identify multiple perspectives that influence a science-related decision or issue *(e.g., consult a wide variety of sources that reflect varied viewpoints on particular topics, such as seat belt use and legislation)*
- develop, present and defend a position or course of action, based on findings
- work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise *(e.g., develop a plan, seek feedback, test and review it, make revisions, and implement it)*
- evaluate individual and group processes used in planning, problem solving and decision making, and completing a task

Attitude Outcomes

Appreciation of Science

Students will be encouraged to:

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not *(e.g., recognize the usefulness of having skills in mathematics and problem solving; appreciate how scientific problem solving and the development of new technologies are related; recognize the contribution of science and technology to the progress of civilizations)*
- value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds *(e.g., recognize the contribution of science and technology to the progress of civilizations; show support for the development of technologies and science as they relate to human needs; consider the research of both men and women)*

Interest in Science

Students will be encouraged to:

- consider further studies and careers in science- and technology-related fields *(e.g., recognize that part-time jobs require science- and technology-related knowledge and skills; maintain interest or pursue further studies in science)*

Scientific Attitudes

Students will be encouraged to:

- evaluate evidence confidently, and consider alternative perspectives, ideas and explanations *(e.g., insist on evidence before accepting a new idea or explanation; critically evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation; critically assess their opinion of the value of science and its applications)*
- use factual information and rational explanations when analyzing and evaluating *(e.g., criticize arguments based on the faulty, incomplete or misleading use of numbers; insist that the critical assumptions behind any line of reasoning be made explicit, so that the validity of the position taken can be judged)*

Performing and Recording

Students will:

Conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information

- carry out procedures, controlling the major variables, and adapt or extend those procedures where required *(e.g., investigate the relationship between acceleration, displacement and velocity)*
- use instruments effectively and accurately for collecting data *(e.g., photogate, stopwatches)*
- estimate quantities *(e.g., estimate, predict, check and validate calculations)*
- use library and electronic research tools to collect information on a given topic *(e.g., determine risks in sporting activities and transportation-related activities)*

Analyzing and Interpreting

Students will:

Analyze data and apply mathematical and conceptual models to develop and assess possible explanations

- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots *(e.g., manipulate and present data through the selection of appropriate tools, such as scientific instrumentation, calculators, databases or spreadsheets)*
- evaluate the relevance, reliability and adequacy of data and data collection methods *(e.g., assess the authority, reliability and validity of electronically-accessed information; evaluate the appropriateness of the technology used to investigate or solve a problem)*
- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information *(e.g., assess the authority, reliability and validity of electronically-accessed information; identify and analyze a variety of factors that affect the authenticity of information derived from the mass media and electronic communication)*
- provide a statement that addresses the problem or answers the question investigated, in light of the link between data and the conclusion *(e.g., delineate cause, effect or correlation between the use of seat belts, seat belt legislation and reduction of fatalities)*
- identify and correct practical problems in the way a technological device or system functions
- construct and test a prototype of a device or system, and troubleshoot problems as they arise *(e.g., test materials for use as seat belts or padding for sports equipment)*
- propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan *(e.g., design ways to reduce whiplash injury caused by rear-end collisions)*
- evaluate a personally designed and constructed device on the basis of criteria they have developed themselves *(e.g., develop criteria to assess a device to reduce whiplash injury)*
- identify new questions or problems that arise from what was learned *(e.g., "How effective are educational programs that promote the use of safety equipment in sports and cars?")*
- identify and evaluate potential applications of findings *(e.g., apply findings to personal behaviour and the development of a safety attitude)*

Communication and Teamwork

Students will:

Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

Collaboration

Students will be encouraged to:

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *(e.g., when designing or constructing devices to solve a practical problem; developing criteria to assess personally constructed devices)*

Safety

Students will be encouraged to:

- show concern for safety, and accept the need for rules and regulations *(e.g., criticize a procedure, a design or materials that are not safe or that could have a negative impact on the environment; consider safety a positive limiting factor in scientific and technological endeavours; use safety and waste disposal as criteria for evaluating an experiment)*
- be aware of the direct and indirect consequences of their actions *(e.g., carefully manipulate materials, being cognizant of the risks and consequences of their actions)*